MULTI CRITERIA DECISION MAKING ON LOAD SHEDDING SCHEME IN AN ISLANDED SYSTEM

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ABSTRACT

Any interruptions to the electrical system can cause loss of the power supply due to the burden of the generator. In industries, interruption in power system can cause million of losses when the shortage of supply occurs. The supply will be back-upped in the storage system. However, if the over demand is uncontrolled, or when there is no decision-making in removing a certain load, there will be a trouble in the power system. The decision should involve removing certain loads depending on some importance or criteria. This requires some decision-making in order to choose the best load(s) to be cut off. In order to do so, Multi Criteria Decision Making (MCDM) can be applied to determine the load shedding scheme in the power system. The objective of this thesis is to justify a load shedding scheme for an islanded power system. This project proposes methodologies for load shedding scheme for the islanded electric power system by using Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In this project, the load shedding scheme is applied to islanded Microgrid Ranau power system. From this project, a series of analyses are conducted and the results are determined. Analyses are made, and the results have shown that AHP, Fuzzy AHP and TOPSIS to determine the load shedding scheme for Ranau Microgrid system. Among these three MCDM methods, the result shown by TOPSIS is the most effective solution because of the effectiveness of load shedding is the highest.

ABSTRAK

Sebarang ganguan boleh menyebabkan masalah kehilangan bekalan kuasa yang boleh membebankan janakuasa. Dalam Industri, masalah ini boleh menyebabkan kerugian yang besar apabila berlakunya sebarang kekurangan bekalan. Bekalan akan disimpan dalam sistem penyimpanan. Walaubagaimanapun, jika permintaan berlebihan tidak dikawal, atau apabila tiada keputusan untuk mengeluarkan beban tertentu, akan menyebabkan masalah dalam sistem kuasa. Keputusan yang dibuat perlu melibatkan pengurangan beban bergantung kepada beberapa kepentingan atau criteria. Ini memerlukan beberapa cara membuat keputusan untuk memilih beban yang terbaik untuk diputuskan. Dalam usaha untuk berbuat demikian, Multi Criteria Decision Making (MCDM) boleh digunakan untuk skim penumpahan beban dalam system kuasa. Objektif projek ini adalah untuk memperbaiki skim penumpahan beban bagi sistem kuasa yang dipulaukan. Tesis ini mecadangkan kaedah skim penumpahan beban dalam sistem kuasa elektrik dengan menggunakan *Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (Fuzzy AHP)* dan *Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)*. Dalam tesis ini, skim penumpahan beban digunakan dalam microgrid Ranau, Sabah. Analisis dijalankan dan keputusan menunjukkan bahawa AHP, fuzzy AHP dan TOPSIS boleh digunakan dalam penentuan skim penumpahan beban dalam sistem Microgrid Ranau Sabah. Antara ketiga-tiga kaedah MCDM, keputusan TOPSIS memberi penyelesaian yang paling berkesan kerana nilai keputusan keberkesanan penumpahan beban adalah yang tertinggi.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Power systems today are much more susceptible to voltage collapses than they were 35 years ago as we increasingly depend on generation sources that are located remotely from load centres. This creates unbalance demand between available power supply and customer demand.

Sometimes this problem will cause some problem where the load shedding needs to be done. Load shedding or rolling blackout is the term used to describe the deliberate switching off of electrical supply to parts of the electricity network, and hence to the customers in those areas. Load shedding can be required when there is an imbalance between electricity demand (customers' usage) and electricity supply (the ability of the electricity network to generate and transport the required amount of electricity to meet this demand. It response to a situation where the demand for electricity exceeds the power supply capability of the network.

There are many types of load shedding scheme approach such as conventional load shedding which is under frequency load shedding scheme. Other than that Florida Reliability Coordinating council California, ISO incorporates Mid Atlantic Area Control (MAAC), Public Service Company of New Mexico (PNM), South West Power Pool (SPP) , Electric Reliability Council of Texas (ERCOT), An intelligent adaptive load shedding scheme proposed by Haibo You et al and much more. [6] Malaysia's TNB system has been using one such scheme. The entire above scheme has been developing to protect their system.

Islanding refers to the condition in which a distributed (DG) generator continues to power a location even though electrical grid power from the electric utility is no longer present or isolated. Figure below shows the electricity demand is expected to reach 1,500 MW by the year 2020.

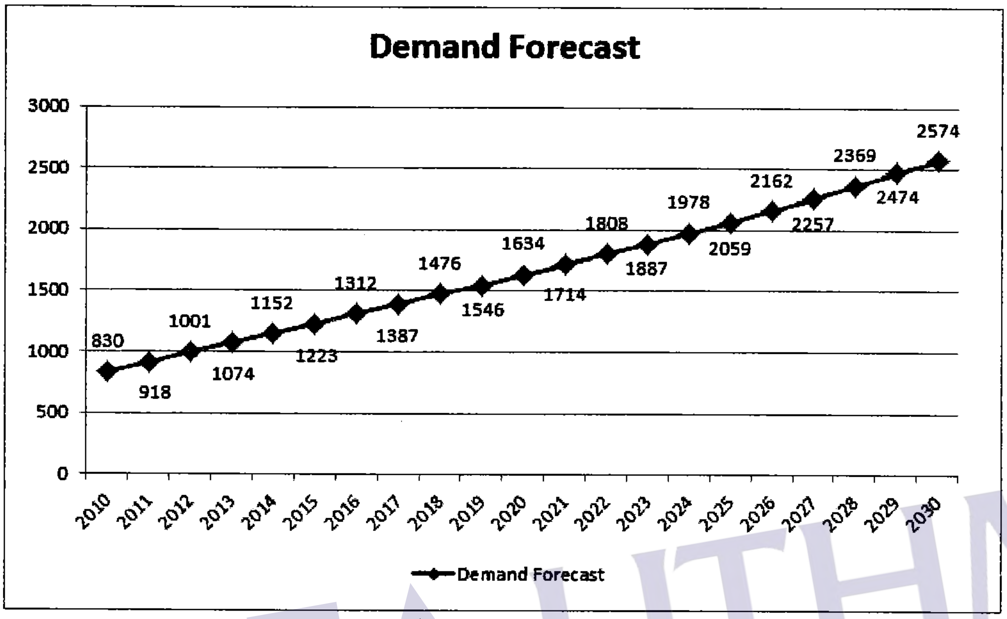
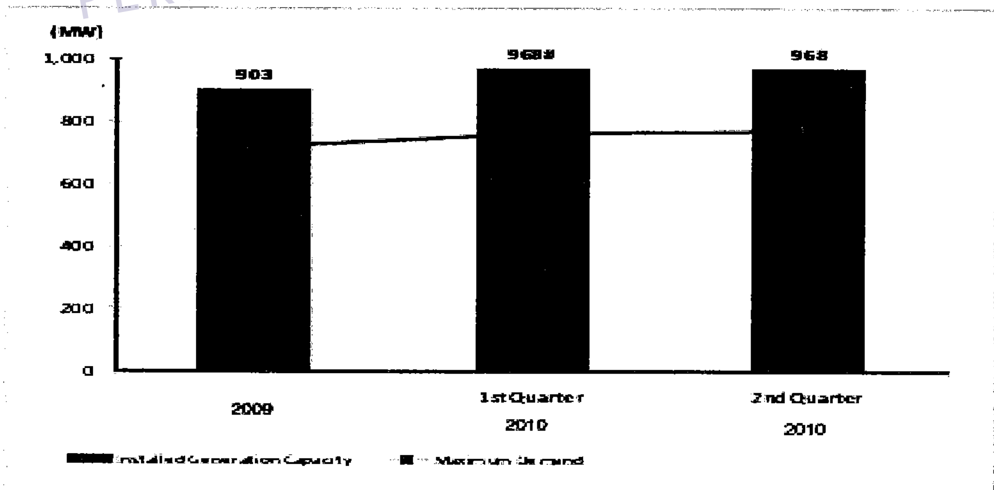


Figure 1.1 : Electricity demand is expected to reach 1,500 MW by the year 2020.

1.1.1 Electricity Supply , Maximum Demand And Installed Generation Capacity



Graph 1.1: Commissioning of the first phase 65 MW open cycle gas turbine in Ranhill Powertron II Sdn. Bhd. In March 2010.

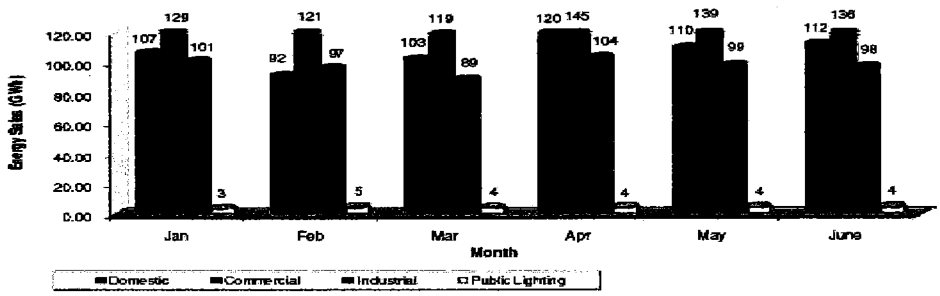
Sabah daily demand increased by 4.2% from 14.2 GWh in 2009 to 14.8 GWh for 2010. Maximum demand was recorded at 779.7 MW in 2010 compared to 718.8 MW achieved in 2009, an increase of 8.5%. Meanwhile, the electricity sales in 2010 increased by 8.1% from 3.818 in 2009 to 4.127 GWh in 2010. Commercial and domestic sector is the dominant sector of electric power demand in Sabah. For now, Sabah electrical supplies are still dealing with the issue of shortage of electric power supply. This is due to the level of preparedness and the reliability of some low power stations mainly diesel-based power stations.

Therefore, some method to increase generation capacity in Sabah has been taken. On March 6, 2010 Ranhill Powertron II (RPII) has started operating capacity of 65 MW GT1, GT2 also followed by a capacity of 65 MW on 10 July in the same year. Overall, the increase in capacity of the power stations in Sabah for the year 2010 amounted to 160.5 MW. This includes the addition of 20 MW of moving power stations at POIC Lahad Datu, 6 MW of biomass plants Teck Guan and 4.5 MW of mini hydro Pangapuyan River.

The total installed generating capacity in Sabah is 1,216.4 MW and the total reliable capacity of 1,111.1 MW. From the overall reliable total capacity, 375 MW or 33.8% is supplied by Sabah Electricity Sdn. Bhd. (SESB) power stations and the rest generated by independent power producer (IPP) generating stations. As the readiness and reliability of low power stations, the system reserve margin calculations had not taken into account.

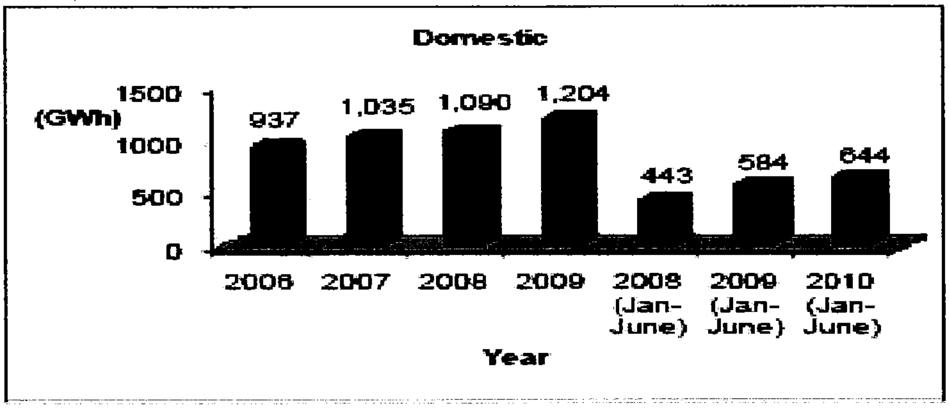
1.1.2 SESB Sales Of Electricity

The following graph below shows the Monthly Sales Electricity of SESB for the first half year of 2010. Graph 1.2 shows the yearly sales of electricity of SESB.

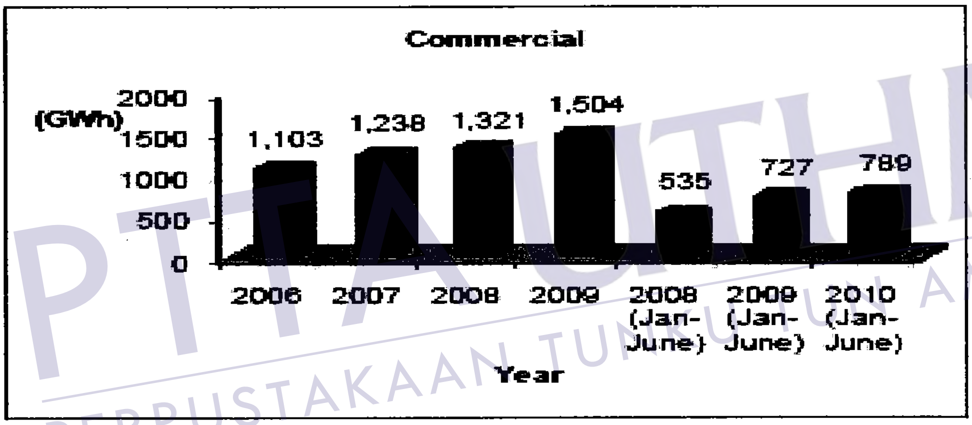


Graph 1.2 : Monthly Sales of Electricity (GWh) of SESB for the First Half Year of 2010.

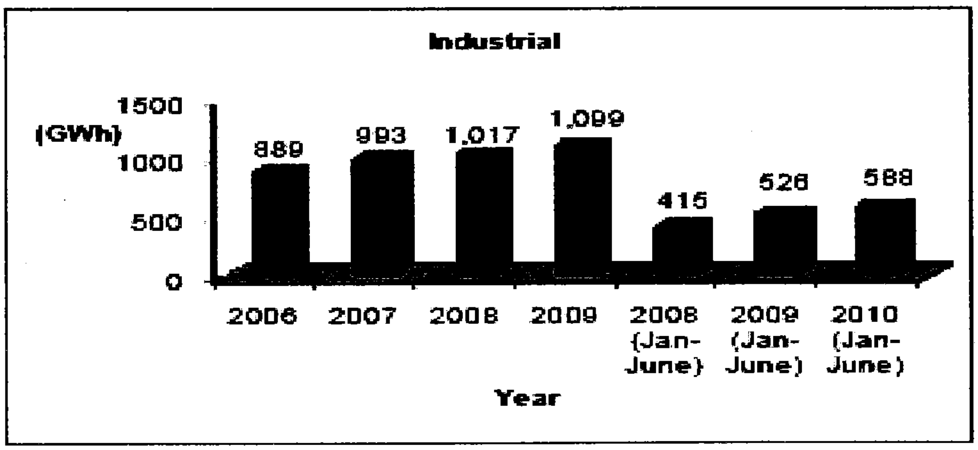
Graph 1.3 shows The Total Electricity (GWh) of SESB for First Half Year of 2008, 2009 and 2010. Graph 1.4 for the Year 2006 to 2009.



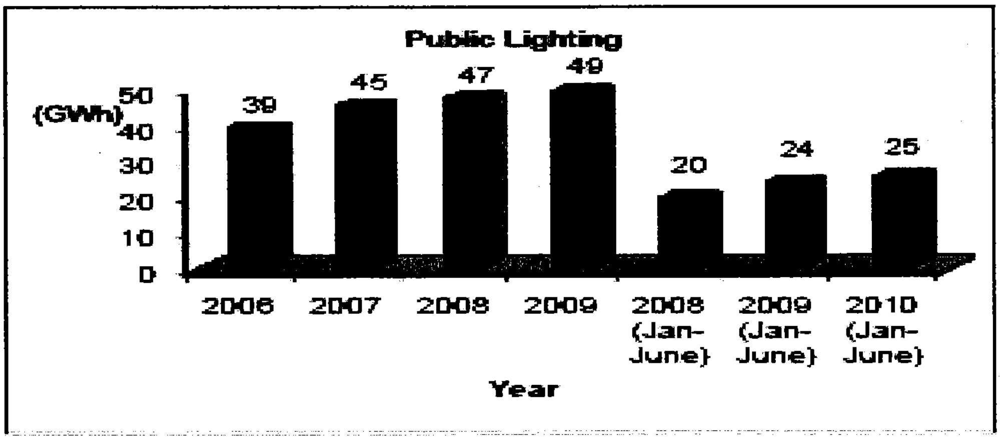
Graph 1.3 : The Total Electricity (GWh) of SESB for domestic consumer



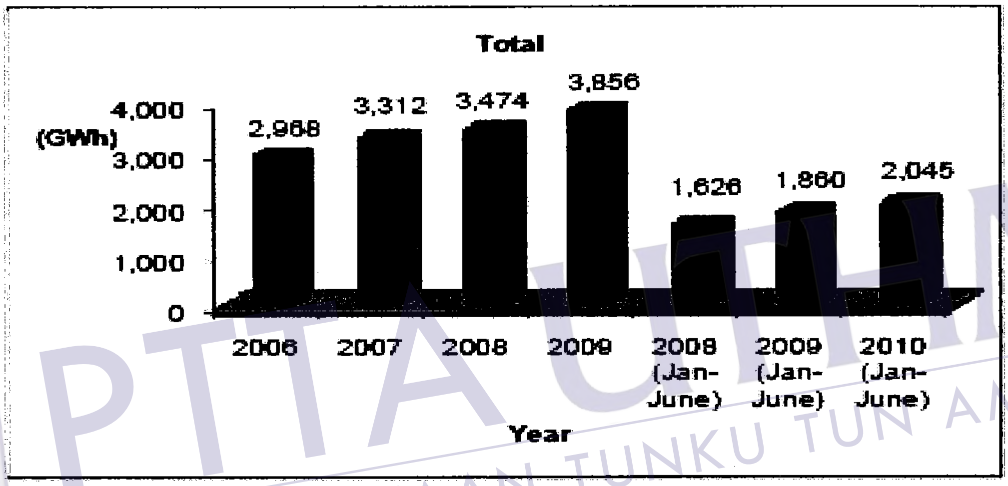
Graph 1.4 : The Total Electricity (GWh) of SESB for commercial consumer



Graph 1.5 : The Total Electricity (GWh) of SESB for Industrial consumer



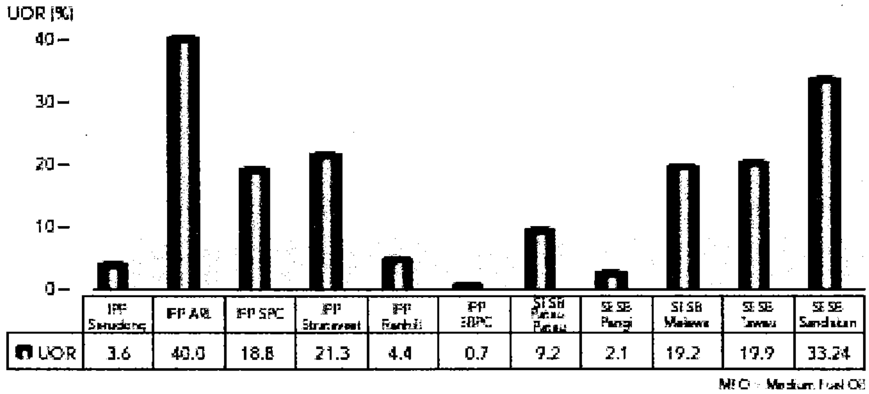
Graph 1.6 : The Total Electricity (GWh) of SESB for public lighting



Graph 1.7 : The Total Electricity (GWh) SESB sales

1.1.2 Performance Of The Service And Electricity Supply In Sabah

Performance of Sabah Generation system. shown in Graph 1.8. In 2010, the rate of unscheduled outages in many IPP generating plants and SESB using diesel fuel is still high due to the damage cannot be avoided. Among the factors that contributed to the damage is like the age of the installation, high operating rates, lack of time to do the Works maintenance, quality of fuel and other. However, new gas plants are performing well and had a low rate of unscheduled outages.



Graph 1.8 : Unscheduled Outages Sabah in 2010

a) SESB Transmission System

Number of appointments in Sabah grid transmission system with the load of 50 MW and above, is less than eight incidents in 2009 and only one incident in the financial year 2009/10. However, the number of reported incidents of discharge load in 2010 increased to 75 incidents compared to 55 incidents in the financial year 2008/09.

Remarks	Sept 09	Oct 09	Nov 09	Dis 09	Jan 10	Feb 10	Mac 10	Apr 10	Mei 10	Jun 10	Jul 10	Aug 10
Number of discharge appointment without load	0	0	0	0	0	0	0	0	0	0	0	1
Number of discharge appointment with load	10	11	14	9	3	4	6	8	7	3	0	0
Energy not supplied during the appointment (MWj)	-	-	-	-	-	-	-	-	-	-	-	31
Average energy not supplied during the appointment (MWj)	-	-	-	-	-	-	-	-	-	-	-	31
The average duration of each appointment (hour:min)	-	-	-	-	-	-	-	-	-	-	-	1:38
Energy not supplied during the of discharge load (MWj)	4192	4105	5515	515 9	114 3	108 1	2579	240 5	3439	157 7	0	0

Table 1.1 : Number of Appointments For Sabah Grid Transmission System With 50 MW Load Loss On Year 2009/10

The blackout incident at the East Coast of Sabah due to line proble both in the 275kV Kolopis - Segaliud with total load loss of 124 MW on 30 September 2007. Voltage Transformer damage in Substation Karamunsing with total load loss of 308 MW on 6 November 2007. The collapse of the 132 kV line tower Kayu Madang in the Universiti Malaysia Sabah due to theft of metal equipment on the tower result in loss of load of 459.3 MW on 21 April 2008.

Year	With blackout	Without blackout
2007 (28 Jul – 31 Aug 2007)	-	18.99
2008	154.38*	11.89
2009	-	31.58
2010	-	20.21

Table 1.2: System Minutes (Delivery Point Unreliability Index (DePUI)) SESB for year 2007 to 2010.

Note:

** Involves three major incidents*

In 2010, the number of appointments for the line and the load cables for each 100cct-km for Sabah grid system increased by 276% compared to 2009. Increased number of appointments was significant at 66kV line.

Line	2006		2007	2008	2009	2010
	East Coast	West Coast	Sabah Grid	Sabah Grid	Sabah Grid	Sabah Grid
275 kV	-	-	-	-	0.20	0.20
132kV	0.46	0.7	5.35	0.28	0.44	0.12
66kV	-	20.99	4.51	5.51	4.34	16.34

Table 1.3 : Total Line Number And Cable CCT per 100-km (With Load Loss) for Year 2006 to 2010

1.2 Problem Statements

Safe operation of a power system requires that system frequency be kept within a specified range. When the generation is insufficient due to disturbances, the frequency might fall under the minimum allowable value, which may lead to system blackout if not properly counteracted. This frequency decline may be corrected by shedding certain amount of load so that the system is back into balanced state.

In Sabah, itself has encounter a lot of interruptions due to various factors. Statistics of supply interruptions in Sabah explains in 1.2.1.

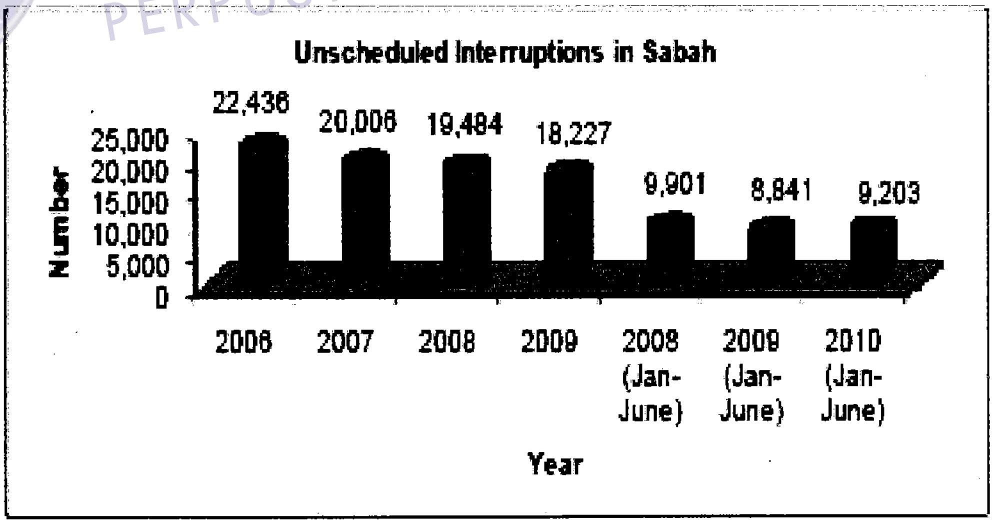
1.2.1 Reliability Of Electricity Supply in Sabah

a) Statistics Of Supply Interruptions In Sabah

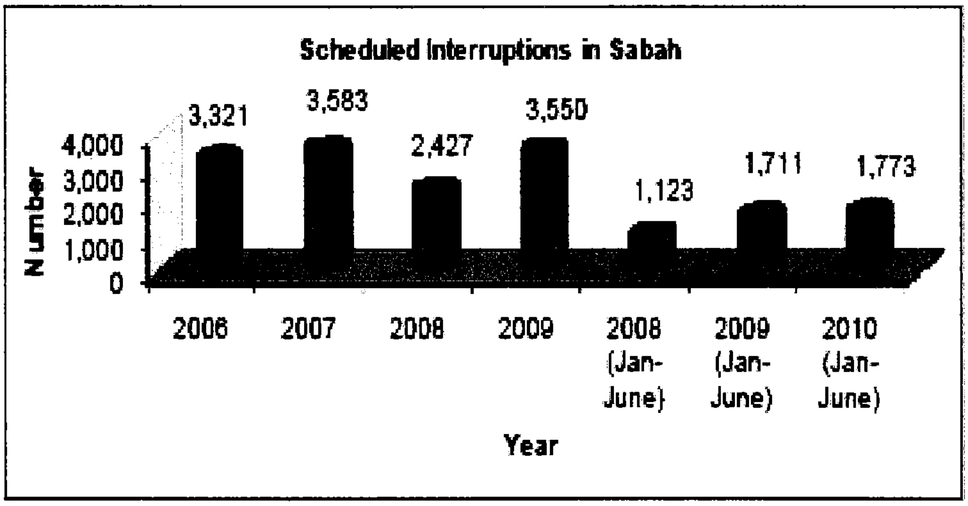
In 2006 there are 22436 unscheduled interruptions occurred. Whereby, there are 20006, 19484 and 18227 unscheduled interruption in the year 2007, 2008 and 2009 respectively. All the following graph shows the numbers of electricity supply interruptions in sabah for :

i) first half year of 2008, 2009 and 2010

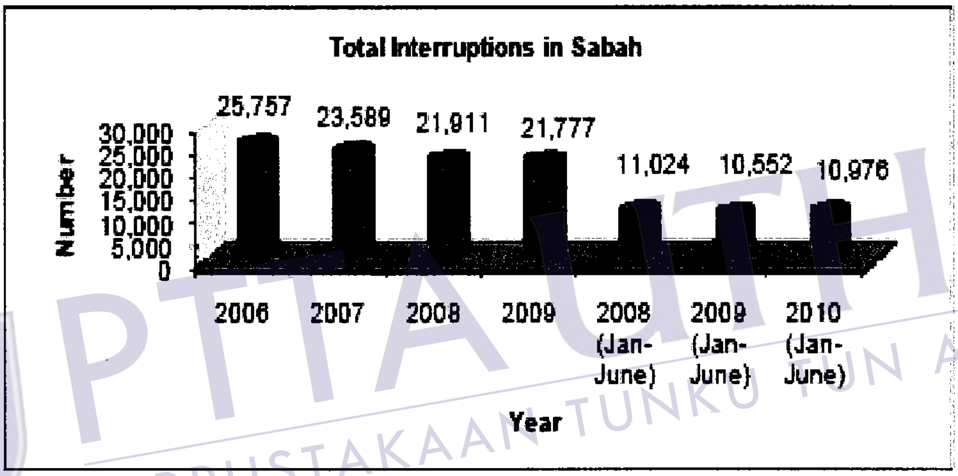
ii) in the year 2006 to 2009



Graph 1.9: Unscheduled interruptions in Sabah

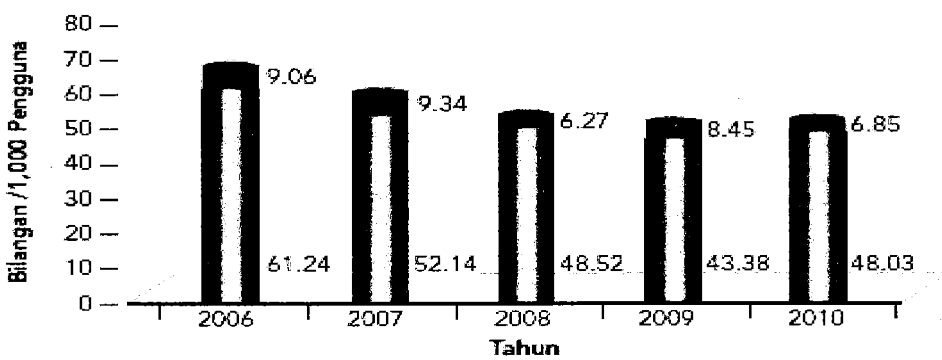


Graph 1.10 : Scheduled interruptions in Sabah



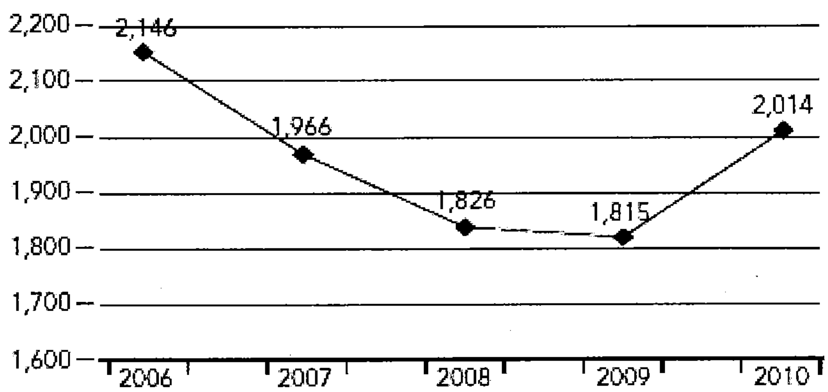
Graph 1.11 : Scheduled interruptions in Sabah

Note : Excluding interruptions in transmission and generation system



Graph 1.12 : total of electrical supply interruption per 1,000 consumer for year 2006 to 2010

In 2010, the number of outages per 1,000 users increased by 5.9 percent compared to 2009. Unscheduled interruption monopolize the total number of outages by 88% from 54.87 interruptions per 1,000 users.



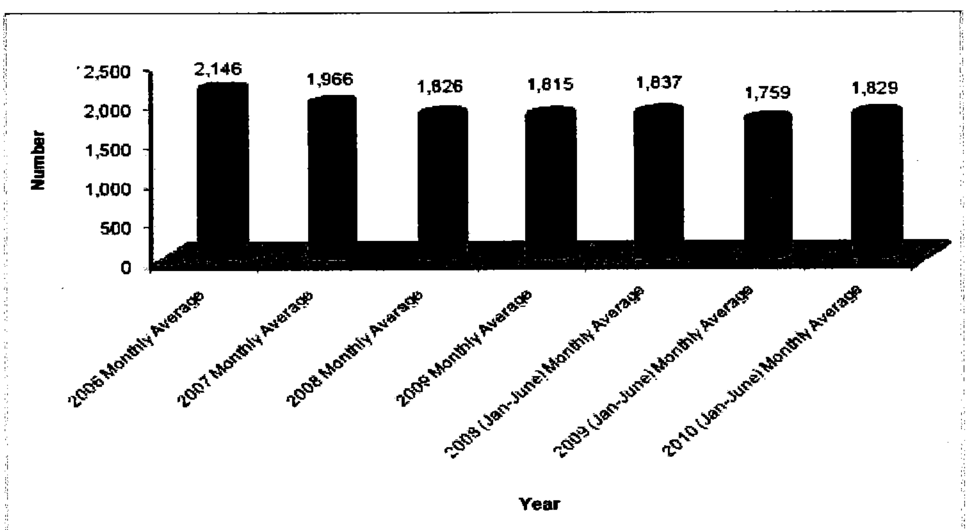
Graph 1.13: Average Monthly Electricity Supply Interruptions Sabah From the Year 2006 to 2010

The monthly average number of electrical disturbances in Sabah increased by 11% from 1.815 in 2009 to 2.014 monthly average number of electrical disturbances in 2010.

Graph 1.14 shows Monthly Average of Electricity Supply Interruptions in Sabah for :

i) First Half Year of 2008, 2009 and 2010

ii) In the Year 2006 to 2009



Graph 1.14 : Monthly Average of Electricity Supply Interruptions in Sabah

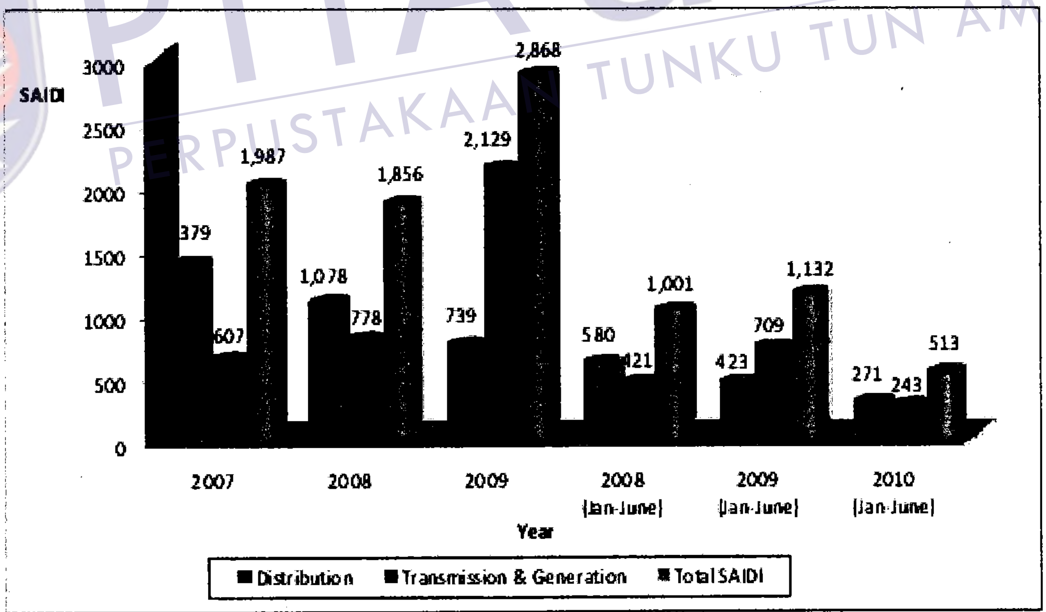
b) Distribution System Of SESB

Performance of the electricity supply in Sabah has improved where SAIDI in 2010 has shown a sharp decline of 76% from 2.868 minutes / customer / year in 2009 to 687 minutes / customer / year. For the year 2010 the central government has been allocated an amount of RM 419 million to SESB to implement various initiatives, including upgrading the electricity supply system to achieve the target of 700 SAIDI minutes in December 2010. Overall, SESB distribution system in 2010 showed a very good performance when compared to the year 2009.

Reading SAIDI distribution system has shown a sharp decline of 41% from 739 minutes in 2009 to 434 minutes in 2010. Similarly, the SAIDI for power generation and transmission system in which the reading was recorded in the year 2010 was of 254 minutes a decrease of 88% compared with the 2009 SAIDI reading of 2.129 minutes. Graph 1.15 shows the SAIDI (Minutes/Customer/Year) in Sabah for :

i) First Half Year of 2008, 2009 and 2010

ii) In the Year 2007 to 2009

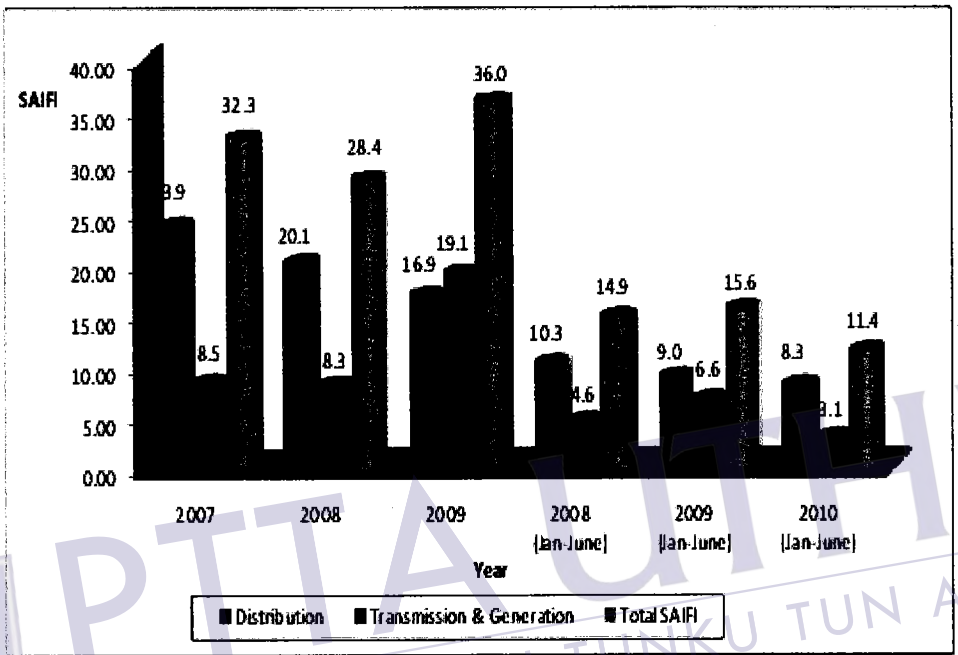


Graph 1.15: SAIDI (Minutes/Customer/Year) in Sabah

In 2010, the total SAIFI decreased by 4.78% for SAIFI Distribution and 79.21% for SAIFI Transmission & Generation from 2009. Graph 1.16 shows the SAIFI (No's of Interruption/Customer/Year) in Sabah for :

i) First Half Year of 2008, 2009 and 2010

ii) ii) In the Year 2007 to 2009

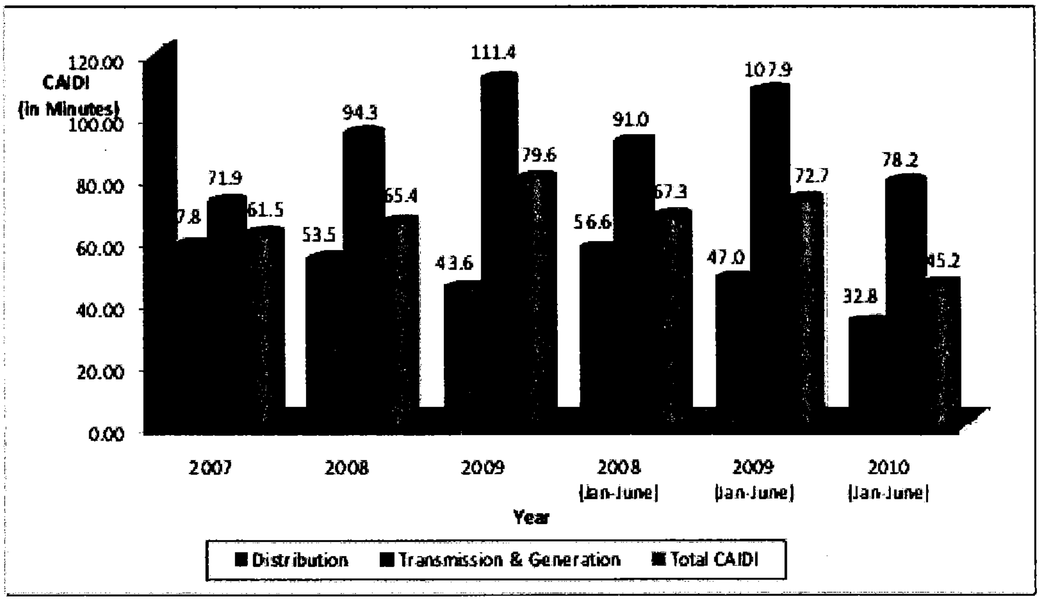


Graph 1.16 : SAIFI (No's of Interruption/Customer/Year) in Sabah

In 2010, CAIDI SESB decrease from year 2009 with a decline of 36.52% to 35.35% CAIDI for Distribution and Transmission & Generation CAIDI. Meanwhile, the overall CAIDI reduced by 54.18%. Graph 1.17 shows the Customer Average Interruption Duration Index (CAIDI)(Minutes/Interrupted customer/Year) in Sabah for :

i) First Half Year of 2008, 2009 and 2010

ii) In the Year 2007 to 2009



Graph 1.17 : CUSTOMER AVERAGE INTERRUPTION DURATION INDEX (CAIDI)*(Minutes/Interrupted Customer/Year) in Sabah*

There are various factors of electricity supply interruptions whereby for unscheduled interruption such as transient factors, natural disasters, overload, third party damage, trees problem, and installation fault/damage. In 2010, the biggest contributor for unscheduled interruptions is installation fault/damage which is 37.2 % followed by trees factors with 15.9%.

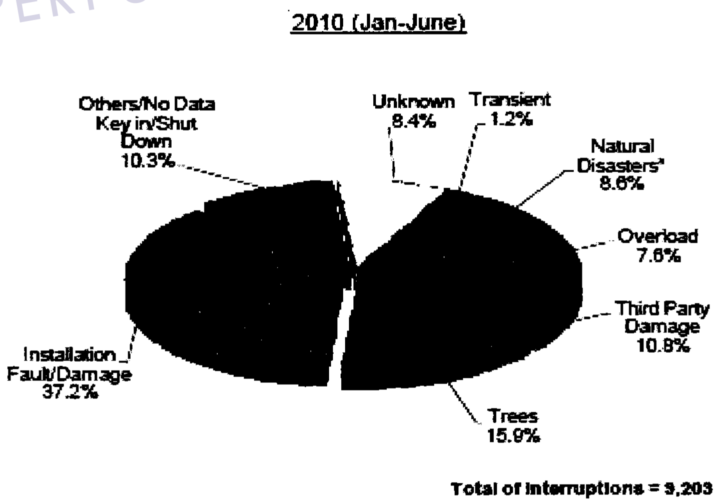


Chart 1.1 : Causes of Unscheduled Electricity Supply Interruptions in Sabah in 2010

(2007 – 2009)

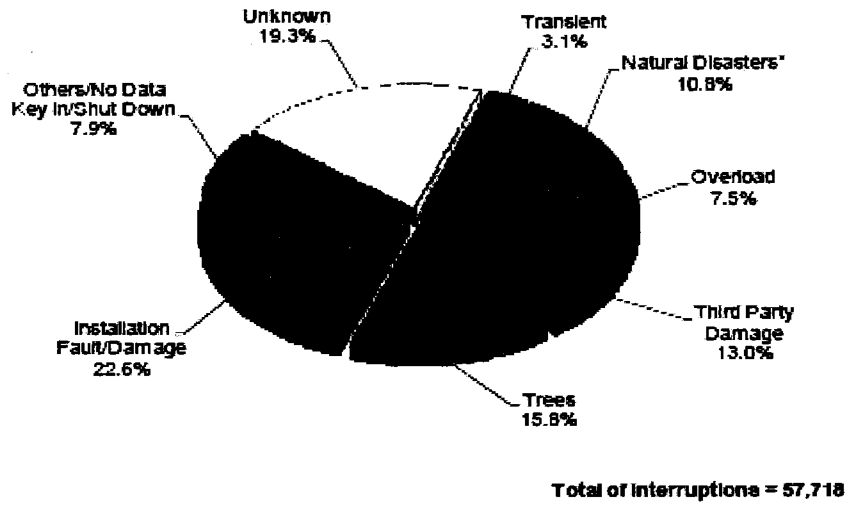


Chart 1.2 : Causes of Unscheduled Electricity Supply Interruptions in Sabah for 2007-2009 (source: TNB *Electricity Supply and Market Regulation Department)*

*Note : * (wind, storm, flood, landslides and etc.)*

In 2007-2009, there are various causes of the electricity supply interruptions such as natural disasters, equipment failures, overload, damaged by third parties, maintenance works, unknown, trees and others. If the interruptions occurred, the electricity Supply Company should take actions to maintain the distribution of the electricity supply of the unaffected area.

The company should reduce the interruptions as minimum as possible. As consumers, people are desired to have continuously distributed electricity supplies without any interruption. For example, the industry will lose a lot of income if there are shortages in the electricity supplies. This thesis will present a system with load shedding scheme for islanded power systems to overcome the problem during electricity interruptions. This thesis will present a system with load shedding scheme for islanded power system to overcome the problem during electricity interruptions.

Based on the above problem, load shedding is needed to make sure the load will be shed. Therefore, there is an action to switching off the electrical supply to parts of the electricity network, and hence to the customers in those areas. It is important to make sure the imbalance between electricity demand (customers' usage) and electricity supply (the ability of the electricity network. Whereby, it will response to a situation when the demand for electricity exceeds the power supply capability of the network.

The load shedding scheme in this research will be analyze to find out the accurate scheme based on four criteria which is frequency, voltage, steady state and transient. In this project, the methods used are Analytical Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

Zeleny (1982) in his book "Multiple Criteria Decision Making" saying "It has become more and more difficult to see the world around us in a one-dimensional way and to use only a single criterion when judging what we see". Hence it is important to choose what type of scheme is more accurate to be implemented in order to provide uninterrupted and reliable services to the customer, deteriorated Infrastructure and to avoid cash loss.

1.3 Project Objectives

The major objective of this research is recommend more appropriate load shedding scheme by using three different Multi Criteria Decision Making Methods. Its measurable objectives are as follows:

a) To identify overload factors and its effect in an islanded system
b) To recommend more appropriate load shedding scheme
c) To analyse the performance on the purpose Load shedding scheme

1.4 Project Scopes

This project is primarily concerned with the load shedding scheme for an islanded system. The scopes of this project are:

a) An islanded system that will be studied is under 11kV which is distribution network.

b) The recommendation of appropriate Load Shedding scheme in term of active power (P) and Reactive power (Q).
c) The analysis will focus on accuracy of the purposed Load shedding scheme

1.5 Project block diagram

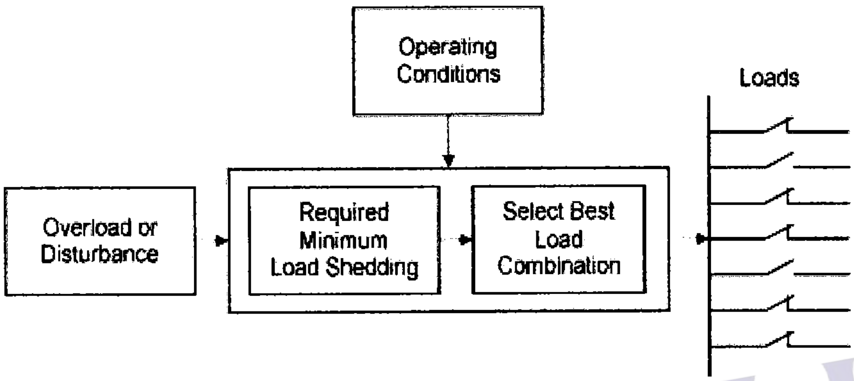


Figure 1.1: Load-shedding strategy based on operating conditions and overload state

Figure 1.1 shows the load shedding strategy based on operating condition and overload state of the overall power system. First step is to identify if there is any overload or disturbance. Is there any, then the next step is to identify which feeder required minimum load and clarify the operating condition. Last select the best load combination to be shed.

1.6 Project Outline

Chapter 1 will discuss the background of the system including the power condition in Sabah. It will also highlights about the background of load shedding with problems in the electrical power system. The objectives and scope of this project are stated in this chapter. Chapter 2 is the literature review of this project. This chapter will give details about the theory of the application in load shedding problems in the electrical power system and theory on Analytic Hierarchy Process (AHP), Fuzzy AHP and TOPSIS. Some previous related researches are listed in this chapter.

Chapter 3 discusses about the project procedure and also approach used to implement the project is explained. Chapter 4 shows the results, data analysis and discussion. The load shedding in the electrical power system by using the Analytic Hierarchy Process (AHP), Fuzzy AHP and TOPSIS is discussed in this chapter.

Chapter 5 presents the project discussion and conclusion. This chapter will discuss about the conclusions of the project and also some future recommendations.

1.7 Summary

This chapter discusses about the introduction for the whole project. Firstly, the project background and the power system condition in Sabah. The concept of the load shedding is introduced in the first part. Next, the problem statement is discussed including the interruption factor which leads to load shedding of the system. Then, the next part is about the objectives and scopes of the project. Lastly, the project outline is discussed which will give an overview about the whole project discussed.

CHAPTER 2

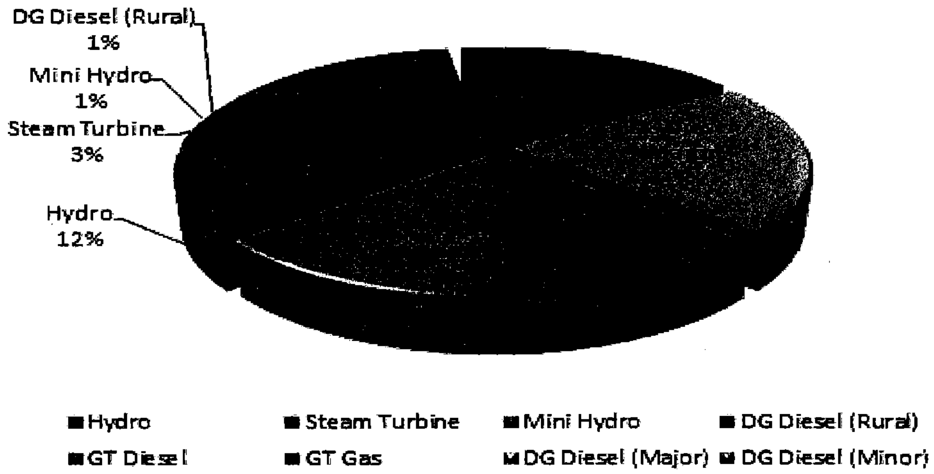
LITERATURE REVIEW

2.1 History of SESB Ranau Sabah Power System

Electricity started in Sabah as early as 1910 supplied by 3 separate organizations. In 1957 these three organizations combined to form North Borneo Electricity Board. When North Borneo joined Malaysia in 1963 and changed its name to Sabah, this entity was renamed Sabah Electricity Board. On 1st of September 1998 Sabah Electricity Board was privatized and became Sabah Electricity Sdn. Bhd. Sabah Electricity Sdn. Bhd. is an 80% owned subsidiary of Tenaga Nasional Berhad (TNB) and 20% by the State Government of Sabah.

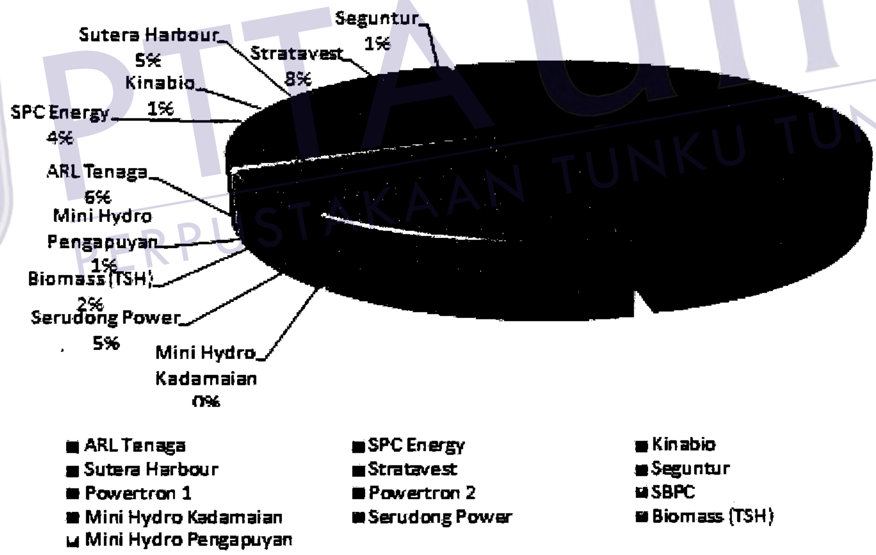
It is a vertically integrated utility providing reliable generation, transmission and distribution services in the state of Sabah and the Federal Territory Labuan. SESB generates, transmits and distributes electricity. It is the only power utility company in Sabah supplying electricity distributed over a wide area of 74,000 sq.km. As of August 2011, 456.406 total of customer which is 82.8% of the customers are domestic customers contributing only 31.17% of the sale.

The SESB installed capacity (excluding IPP) of the Sabah Grid which supplies electricity for major towns from Federal Territory Labuan to Tawau is 430.9 MW and the maximum demand is 830 MW (as of August 2011). Graph shows the Istalled Capacity by plant type. SESB has 46 station and 12 Independent Power Producer (IPP) excluding KKLW station. Power generated for year 2011 is 1089GWh (SESB) and 3819 GWh (IPP) for Sabah power system interconnection.

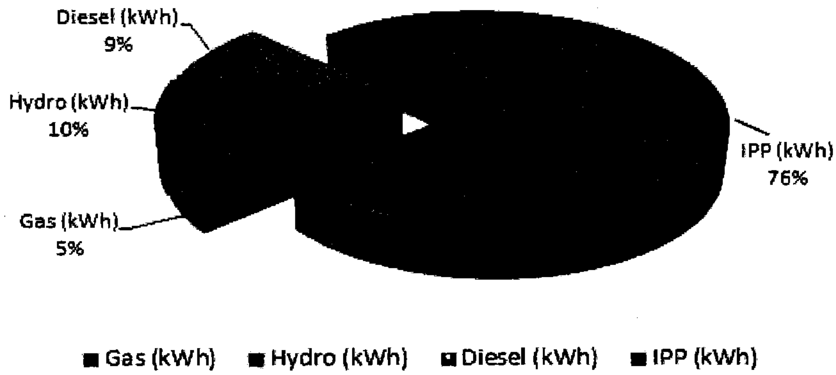


Graph 2.1: Installed Capacity by plant type

Graph 2.1 shows the numbers of installed capacity by plant type. The biggest contributor is Diesel Generator Minor which is 27% followed by DG Diesel Major 21%.



Graph 2.2: IPP Installed capacity by station



Graph 2.3: Generation mix SESB for year 2011

2.1.1 Transmission Parameters

275 kV	492.00
132 kV	1596.50
66 kV	100.34
Total:	**2188.84**
132 kV	80.90
66 kV	22.16
Total:	**103.06**
132 kV	29.00
275 kV	2
132 kV	29
66 kV	8
Total:	**39**

Table 2.1: Transmission line parameter

Sabah power system has 2188.84 circuit-km length of overhead line, 103.06 circuit-km length of underground cable, and 29.00 circuit-km length of submarine cable.

Total number of main intake substation is 39 and 3263 numbers of transmission towers. It also has 84 power transformers.

[redacted]	
275/132/33 kV	4
275/11 kV	1
132/66 kV	10
132/33 kV	30
132/11 kV	18
66/33 kV	1
66/11 kV	20
Total:	**84**
[redacted]	
275 kV	663
132 kV	2451
66 kV	149
Total:	3263

(Continue) Table 2.1 : Transmission line parameter

2.1.2 Distribution System Capacity as at January 2012:-

	[redacted]						
No. of PPU	0	2	7	10	7	19	5
No. of PE 11/22kV	1,634	805	726	670	1,062	531	278
[redacted]							
ABC 33kV	0	52	25	42	33	30	0
Bare 33kV	0	10	103	129	25	115	31
ABC 11kV	24	152	100	129	25	115	31
Bare 11kV	1,367	1,424	859	654	568	784	151
[redacted]							
33kV	0	80	0.55	21	42	4	31
11/22kV	151	114	37	282	97	40	101

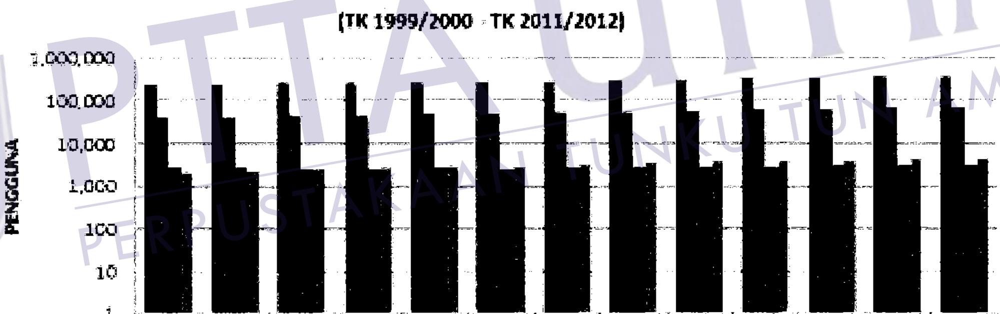
Table 2.2: Distribution System Capacity as at January 2012

2.1.3 Electricity Consumption (GWH) as at Dec 2011:-

Domestic	464.68	31.50%
Commercial	631.33	42.70%
Industrial	361.85	24.50%
Public Lighting	19.16	1.30%
Total Consumption	1,477.02	**100.00%**

Table 2.3 : Distribution System Capacity as at January 2012

Commercial consumer has the highest consumption of the electricity which is 42.7 %, followed by domestic consumer with 31.5% and industrial consumer of 24.5%. Public lighting consumes about 1.3% of the electricity. Table 2.3 shows the distribution system capacity of electricity by sectors.



	TK 1999/ 2000	TK 2000/ 2001	TK 2001/ 2002	TK 2002/ 2003	TK 2003/ 2004	TK 2004/ 2005	TK 2005/ 2006	TK 2006/ 2007	TK 2007/ 2008	TK 2008/ 2009	TK 2009/ 2010	TK 2010/ 2011	TK 2011/ 2012
■ Domestik	236,91	248,95	258,27	265,79	277,03	287,27	301,45	314,11	327,70	342,81	354,49	377,85	384,38
■ Komersil	42,626	44,555	46,297	47,550	49,308	51,286	53,973	57,257	60,831	64,302	67,130	71,287	72,189
■ Industri	2,643	2,632	2,626	2,598	2,630	2,625	2,649	2,684	2,759	2,839	2,916	2,864	2,865
■ Lampu Awam	2,144	2,279	1,489	2,642	2,894	3,051	3,282	3,644	3,855	4,029	4,175	4,398	4,516

Table 2.4: Total of consumer by tariff

Graph 2.3 explained about the total of consumers by tariff. Domestic has more than 100 thousand of consumers, followed by commercial, industrial and public lighting.

The Sabah Grid is made up of 66kV, 132kV and 275kV which link up all major towns in Sabah and Federal Territory of Labuan. As of March 2011 the total length of transmission line in Sabah is 3,263 km. However, Ranau microgrid is not connected to Sabah Grid even though a few attempts to connect Ranau Microgrid to Sabah Grid. Ranau Microgrid is a complete power system consists of generation system, transmission system and distribution network. This system has 14 generators and 2 minihydro. The total install capacity of generation is 15.2 MW, however the available capacity only 7.74MW.

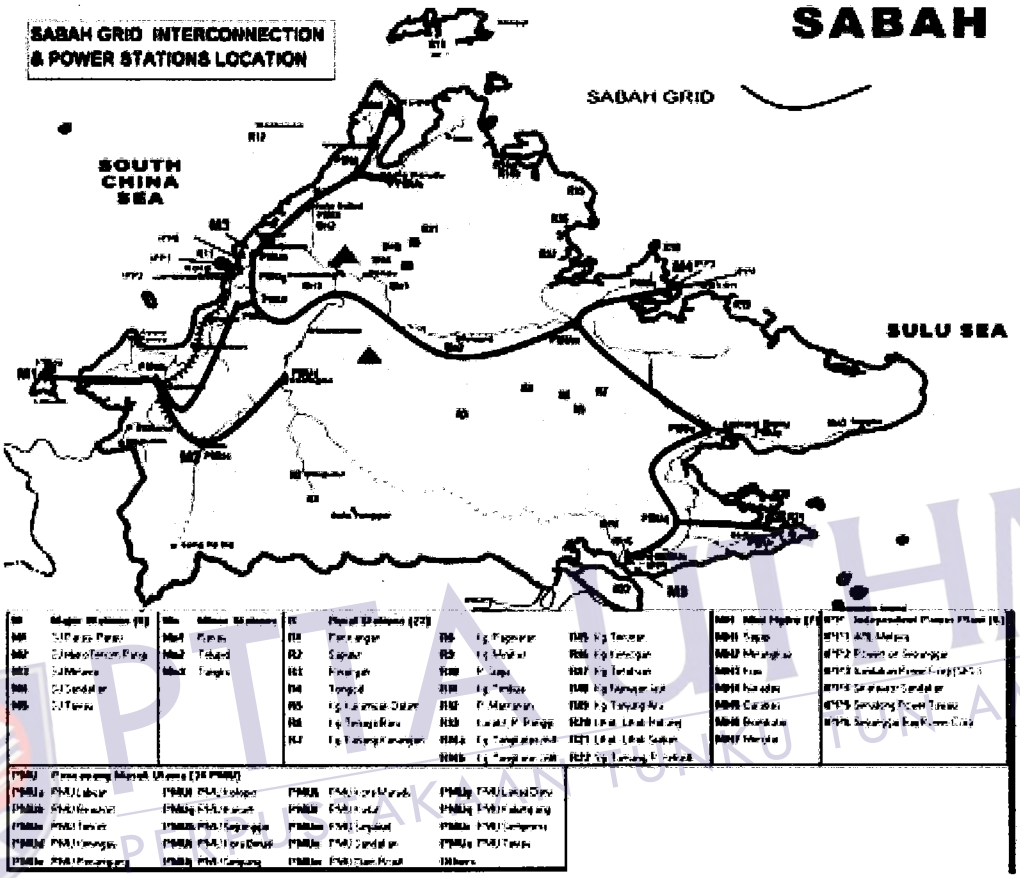


Figure 2.1: Sabah Grid

Ranau, a district in Sabah, supplied with electricity in the early 1960s. During the early years, the supplies were 12-hour system. During that time, consumers served from 0600 hours to 1800 hrs. Only three areas supplied with electricity namely Lohan, Bundu Tuhan and Kundasang. Each areas connected it's own generators. The three loads were interconnencted during the mid 1980s. Starting in the 1970s, Ranau district supplied with 24 hours electricity.

At present Ranau electricity system, the only area serviced with 12-hour system is Matupang. At Paus village, infrastructures are currently developed to supply the village with solar powered electricity. About 80 houses will benefit from this solar powered generator.

In the Ranau district infrastructure masterplan, Rural Electrification Programme (BELB - Bekalan Elektrik Luar Bandar) currently installing electricity infrastructures at Melinsou, Segindai and Timbua area.

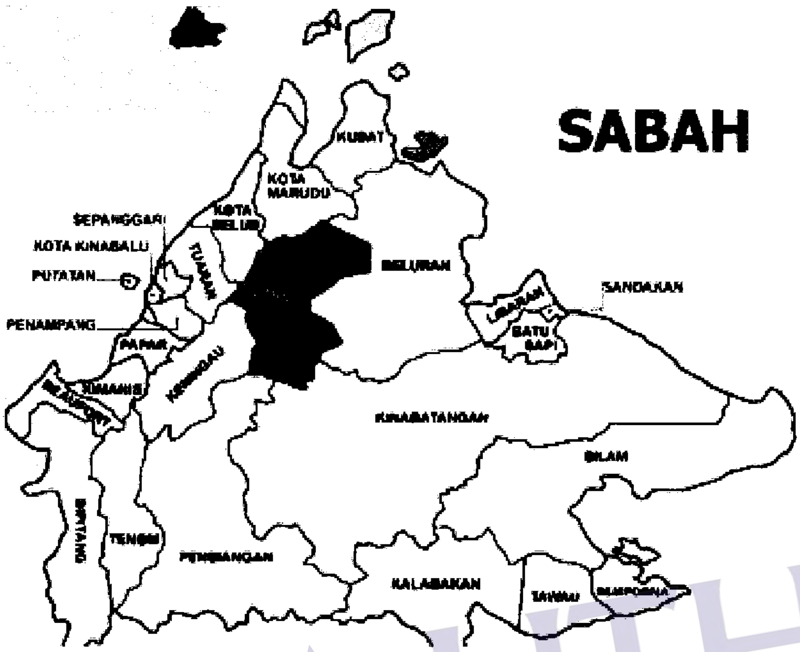


Figure 2.2 : Location of Ranau Micro grid

2.2 Theories of Multi-criteria Decision Making

In this chapter some important theories will be discuss. For example load shedding scheme for an islanded system, AHP, fuzzy AHP and TOPSIS multi criteria decision method.

2.2.1 AHP

The Analytic Hierarchy Process (AHP) is due to Saaty (1980) and is often referred to, eponymously, as the Saaty method. Since 1977, Saaty proposed AHP as a decision aid to help solve unstructured problems in economics, social and management sciences. AHP has been used for modelling unstructured problem in various areas including everyday problem, complex problem of decision making, social and economy The AHP enables to structure a complex problem in the form of a simple hierarchy and to evaluate quantitative and qualitative factors in a systematic manner under multiple criteria environment in confliction AHP is a method to develop a numerical score to rank each decision alternative based on how well each alternative meets them. [5]

In AHP, preferences between alternatives are determined by making pairwise comparisons. In a pairwise comparison, the decision maker examines two alternatives by considering one criterion and indicates a preference. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference. The standard preference scale used for AHP is 1-9 scale which lies between "equal importances" to "extreme importance" where sometimes different evaluation scales can be used such as 1 to 5.

In the pairwise comparison matrix, the value 9 indicates that one factor is extremely more important than the other, and the value 1/9 indicates that one factor is extremely less important than the other, and the value 1 indicates equal importance. Therefore, if the importance of one factor with respect to a second is given, then the importance of the second factor with respect to the first is the reciprocal. Ratio scale and the use of verbal comparisons are used for weighting of quantifiable and non-quantifiable elements.

The application of the AHP to the complex problem usually involves four major steps:

1. Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form.

2. Make a series of pair wise comparisons among the elements according to a ratio scale.

3. Use the eigenvalue method to estimate the relative weights of the elements.

4. Aggregate these relative weights and synthesize them for the final measurement of given decision alternatives.

The essence of the process is decomposition of a complex problem into a hierarchy with goal (criterion) at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision alternatives at the bottom of the hierarchy.

Elements at given hierarchy levels are compared in pairs to assess their relative preference with respect to each of the elements at the next higher level. The method computes and aggregates their eigenvectors until the composite final vector of weight

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